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Examining rural Sahelian out-migration in the context of climate change: An analysis of the linkages between rainfall and out-migration in two Malian villages from 1981 to 2009

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ABSTRACT

Subsistence farmers in Sahelian Africa are highly vulnerable to the rainfall effects associated with climate change. Permanent or temporary out-migration can provide an individual or family the opportunity to mitigate against these effects. One major challenge to quantifying the impact of climate change on out-migration is lack of appropriate spatial and temporal data. Out-migration data must be adequately detailed to include both long- and short-term departures. The climate data must provide fine scale, community-specific detail. To examine the climate variability as a factor of out-migration we examine individual- and community-level responses using highly detailed, full migration histories of 3150 individuals with fine-scale rainfall data. Using this multi-method approach we examine the probability of out-migration as well as out-migration duration and destination as they relate to locally measured rainfall. The results suggest that out-migration behavior does not generally change because of failures or variation in the rainy season.

1. Introduction

Climate change in the form of warming and increasingly variable precipitation (IPCC, 2013) will force subsistence farmers around the world to respond in ways that are not yet well understood. Given the extensive poverty, limited infrastructure and dearth of economic opportunities, perhaps no other community on earth is as vulnerable to the negative effects of increased rainfall variability, a key component of climate change, as subsistence farmers in sub-Saharan Africa (Nielsen & Reenberg, 2010; Hulme, 2001). Based on historical evidence, one potential response is out-migration – where farming families or individuals from farming communities will leave their origin community (Kniveton, Schmidt-Verkerk, Smith, & Black, 2008; McLeman & Smit, 2006; Nawrotzki, Riosmena, & Hunter, 2013). These moves can be either permanent or short-term, domestic or international (Henry, Schoumaker, & Beauchemin, 2004; Hunter, Murray, & Riosmena, 2011). The underlying motives to migrate may reflect an individual's goal to create a new life in a community more resilient to climate change impacts. As part of the environmental scarcity hypothesis (Hunter, Luna, & Norton, 2015) out-migration may serve more as a coping strategy from families to diversify livelihoods and to outsource the feeding costs of some of their members (Findley, 1994; Eakin, 2005; Ezra & Kiros, 2000, 2001).

While out-migration in sub-Saharan Africa has been actively researched in a number of different settings and over different time-periods, inconsistent results support the importance of empirical research in this area. One of the primary limitations to developing a comprehensive theory and understanding of the linkages between out-migration and climate is the lack of appropriate data and empirical analyses (Gemenne, 2011). In particular, studies evaluating individual-level variation like gender and age, as well as studies that investigate individual migration behaviors in a cultural context where circular migration is already well established are extremely limited (see Black et al., 2011; Hunter et al., 2015; Carr, 2005). Investigating the ways in which people use out-migration in communities where circular migration exists are important because they challenge different biases (see Castles, 2011) that may be related to ideas that migration is a problem. Data covering relatively long periods of time and documenting

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migration in rural, poor communities where circular migration is common is unusual. Gathering detailed and long-term series of migration data is beyond the scope of the standard country-level population data collection programs (primarily the Demographic and Health Survey data) or censuses which are focused on cross-sectional collection efforts. Data from thoroughly detailed individual migration histories, including men's and women's experiences is ideal but generally only covers relatively short time periods (see Henry et al., 2004).

In this research we aim to contribute to the growing body of studies focused on climate and out-migration through an examination of the migration dynamics in a delineated rural area in southeastern Mali. We focus on the individual out-migration behaviors of both men and women in the community, as well as the aggregate community out-migration dynamics. We use detailed migration histories, recorded by life history surveys ($N \sim 3150$) to measure migration. While to measure the changes in climate as a proxy for community resources (agriculture), we focus on inter- and intra-annual rainfall variability – the most significant environmental parameter impacting people in West Africa (Brooks, 2004; Hulme, 2001; Nielsen & Reenberg, 2010). The connection between rainfall and migration behaviors will be examined over a period of 28 years, 1981–2008, the period covered by both series of data. This period of time contains one of the most extreme droughts in the history of modern Sahelian Africa (the drought of 1984) as well as periods of less severe water shortages and periods of adequate and relatively consistent rainfall.

2. Background

A firmly established hypothesis in research focused on coping strategies in cases of economic stress, particularly as it relates to environmental stressors (droughts, floods, etc.), is that there will be an increase in out-migration, particularly among men (see McKenzie, 2003; Skoufias, 2003; Mortimore, 1989, as well as the 2001 World Bank framework). In rain-fed agricultural areas where major or minor food deficits may occur as a result of annual variability in crop yields corresponding to inconsistent rainfall patterns, out-migration may provide one vital and flexible coping strategy (Guilmoto, 1998; Hampshire & Randall, 1999, Hill, 1990; Reardon, Matlon, & Delgado, 1988; Roncoli, Ingram, & Kirshen, 2001; Henry et al., 2004). If a family sends a few members to earn money in other near or distant communities, those out-migrants are able to send money back to their families of origin or are able to return with goods needed by the household.

Droughts, floods or other climate events may serve as "push" factors, especially for young men – presumably in search of resources to aid their families in times of crises – but possibly also for women and children as a way of reducing the local resource demands (Findley, 1994; Henry et al., 2004; Roncoli et al., 2001; Hampshire, 2002). Further, out-migration destinations and durations may also be impacted by climate or weather events (Findley, 1994). On one hand, destinations with labor demands might draw individuals who are facing resource constraints. Alternatively, and consistent with Lee's classic push-pull migration model, costs associated with the travel to the communities may be too great of an obstacle to overcome and might reduce the out-migration of the poorest people (Lee, 1966; Findley, 1994; Nelson, 1983). Given that traveling greater distances brings greater costs, it is probable that years where families are resource constrained, out-migration destinations may be nearer to the sending community. Consistent with nearness of the destination community, the length of time of an out-migration, or even the permanence of the out-migration, can potentially be impacted by the weather event. After a series of poor rainfall seasons or following a major drought or flood, individuals could permanently relocate to a new community in an effort to adopt a new type of livelihood that is less weather dependent (Henry et al., 2004; Findley, 1994).

Temporary out-migration (as a component of circular migration) is an institution in the Sudano-Sahelian region (Guilmoto, 1998; Cordell, Gregory, & Piché, 1996; Piché & Cordell, 2015). Temporary out-migration has become an integral part of family economy in many settings, and is well established in many rural West African populations. Here, people in agricultural communities move for work during the dry season when labor demands on their own fields are less. These people often come back to the village during the rainy or harvest seasons for agricultural activities. Temporary out-migration is a strategy used by many families to diversify the sources of economic resources, an example of livelihood diversification, and to adjust to economic crises or constraints or unusual needs and can involve short-term moves to urban areas or to rural villages that are closer in geographic proximity.

Temporary out-migration in many of these communities frequently occurs in years without drought or other identifiable environmental event (Ezra, 2001; Hertrich & Lesclingand, 2012a, 2017). In fact, research of the 1984 drought and temporary out-migration in Mali has indicated that this major drought did not actually cause an overall increase in out-migration, but it did cause an increase in the number of short duration out-migrations to nearby communities (Findley, 1994). Findley (1994) suggests that the reasons for this may be because the communities had already reached a maximum level of out-migration and so rather than increasing the level of out-migration during times of strife, people modified their behaviors to reduce the cost and risk. This research provided important insight into the ways that communities accustomed to out-migration responded to drought but, because of data limitations at the time of analysis, relied on no place specific rainfall data and a short time series of out-migration behaviors. In this research we aim to build on research by Findley and other and advances scientific understanding of migration and climate using a more detailed time series of out-migration and rainfall data. The data allow us to look at behavioral change over time and with attention to annual variability in season quality.

3. Approach and hypotheses

The livelihoods diversification framework is part of a broader theory that suggests that households may send individuals to invest their labor into other markets as part of a household risk diversification strategy (Hunter et al., 2015). We use this framework to investigate the relationship between rainfall variability and out-migration in two agriculture-dependent Malian villages where temporary out-migration is well established. We hypothesize that in poor rainfall years the communities under study will experience either an increase in out-migration or changes in migration behaviors, as migrants and their families seek opportunities to diversify their income sources and reduce risk. Ultimately, we aim to apply the livelihoods framework in a way that acknowledges the specific culture, history and uniqueness of the communities under study while also contributing to the ongoing discussions of environmental push-factors in rural, rainfall dependent communities. Key to this project is our consideration of "how people apprehend, negotiate, and transform their local context in a manner that links environment to migration" (Carr, 2005, pg 929). By developing a rainfall index reflecting West African farmer's experiences and perceptions of climate change we aim to create a contextually relevant and fine-temporal scale measure of seasonal rainfall variability that will provide insight into how people apprehend and respond to their environment. The focus on within season weather

characteristics of two small and relatively homogenous rural communities over a 29-year period allows for a more precise investigation of the relationship between rainfall and out-migration in vulnerable, subsistence communities.

Our specific objective is to examine if rainfall, as related to agricultural stress, is a driver of out-migration in this population of Sahelian farmers. The high level of detail in both the rainfall and the out-migration data allows us to construct contextually relevant hypotheses to evaluate the linkages between climate and migration. We expect to bring out specific patterns when we take into account a migrant's individual characteristics, specifically sex and age. Given the high level of out-migration among young adults and important sex-based differences in both marriage patterns and labor (Hertrich & Lesclingand, 2012b, 2017), we anticipate that men and women will respond differently to rainfall variability.

We examine the following questions using macro-level and micro-level analytic approaches:

1. ***How are weather and out-migration correlated? Is rainfall stress a driver of out-migration?***
2. ***Are there typical out-migration patterns corresponding to age, sex and migration experience that are associated to rainfall variations?***

Analytic approach 1: correlation between rate of out-migration and annual rainfall
Analytic approach 2: individual out-migration behaviors, specifically duration and destination, as a response to rainfall variation

4. Study site

The study population is in the Bwa ethnic region of Southeast Mali, about 450 km from Bamako, close to the Burkina Faso border. The population relies on family-based agricultural production, mostly food crops, grown during the relatively short rainy season (June–September). Attitudes and behaviors towards childbearing support large families and fertility remains high, at about eight children per woman and nine children per man (Hertrich et al., 2012). Migration is common, but mainly within Mali or to neighboring countries. There is no culture of migration to Europe. Schooling developed in the 1990s but is still limited with around half of children attending primary school at the end of the 2000s. The area is very homogeneous, with little socio-economic, educational and cultural variation between villages and families. The cultural and economically homogeneous population, dependent on rainfall for food production, facilitates an investigation of migration as a response to rainfall variability because so many other relevant factors are common across the population over time.

5. Data and methodology

5.1. Population data

Our data are based on a longitudinal project, SLAM (Suivi Longitudinal au Mali[1], Hertrich, 1996) first implemented in 1987–89 and updated every five years, the latest being 2009–2010. It includes highly detailed life history data collected over 20 years in two villages (1750 inhabitants in 2009). The survey recorded the matrimonial, reproductive, migratory and religious histories of men and women of all ages. Migration histories were recorded from birth until the last round of the survey (Lesclingand, 2004; Hertrich & Lesclingand, 2012a; Lesclingand & Hertrich, 2017). Any out-migration lasting longer than three months was recorded. The fine temporal scale allows for the inclusion of short-term, seasonal and circular moves, which are common in West Africa. Information regarding destination and reason for out-migration are also included, as well as various data on the context of out-migration and family involvement. During each round of the survey, the biographies previously recorded were updated, and those of new residents – i.e. in-migrants and the children born since the last visit – were recorded. For people absent at the time of a survey collection period (due to out-migration), the information was obtained from relatives, up to the first marriage for women, and up to the current survey visit for men.

Our analysis focuses on the individuals who were interviewed as residents during at least one of the SLAM visits, between 1988 and 2010 (about 3150 individuals). The use of these longitudinal data limits the bias inherent to retrospective surveys; indeed, the only out-migrants not included in our analysis are those who left before 1988 (first survey) and have not returned to the village since that date. An under-estimation of out-migration potentially arises in the period before 1988 and may result in a bias of trends that complicate comparisons of out-migrations before and after this period. However, two data-quality analyses suggest that these limitations do not prevent an analysis of out-migration using the data. First, a large majority of male out-migrations[2] are temporary, meaning that the out-migrations before the first survey (1988) that did not end before the last round of the survey (twenty years into the future (2009–10)), represent a minority. We assume these extended absences make up less than 10% of out-migrations[3]. Second a detailed analysis examining out-migrants through genealogical data (Hertrich & Lesclingand, 2012b) provides evidence that the bias does not significantly affect the trends in out-migration during adolescence and the beginning of adulthood, the ages with the highest concentration of migrations (see below).

5.2. Rainfall data

For the rainfall data, this study uses the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (Funk, Peterson, et al., 2014). The CHIRPS data set, developed recently by USGS scientists in collaboration with Climate Hazards Group at University of California at Santa Barbara, combines a high resolution (0.05°) climatology (Funk et al., 2012; Funk et al., 2015) with time-varying station data and observations from geostationary weather satellites. CHIRPS period of record, 1981-present, compares reasonably well with in situ rain gauge observations (Tote et al., 2015) in Africa. CHIRPS is well suited to evaluating within- and between-yearly and seasonal variation (Tote et al., 2015). USAID supported research projects use CHIRPS for monitoring and forecasting rainfall across Africa (Funk, Hoell, et al., 2014). The rainfall data which are spatially representative at the level of the villages and are used to quantitatively evaluate the overall seasonal rainfall totals that we consider as a proxy for crop productivity and ultimately local food production and availability.

6. Analysis

A major challenge in population-environment analysis is the proper merging of concepts and data (Mertz, 2009). In other words,

[1] http://slam.site.ined.fr/.

[2] The situation is different for women who move when they get married to join their husband's families. The survey does not follow women's out-migration after they get married, making it difficult to rigorously compare men's and women's migration into adulthood.

[3] Among male out-migrations registered since 1988 (and controlling for the time of observation), about 60% of out-migrations last<1 year, 80% are completed within 4 years, and 16% last at least 8 years.

the way a scientist might evaluate rainfall to determine the quality of a given year is potentially very different than the strategies used by an individual or family dependent on rainfed agriculture. In acknowledging the important conceptual challenges in linking rainfall and out-migration behaviors we aimed to construct several context-specific indicator variables for both rainfall and out-migration that incorporated these complexities. We describe the indicators below.

6.1. Climate indicators

Harvest occurs near the end of the rainy season and in typical years a harvest can produce sufficient food to support the family adequately until the following year's harvest. Because of the time lag – a poor rainy season does not immediately result in food deficiencies – in this analysis we evaluate the previous year's rainfall as the motivator for the current year's out-migration. In this way the analysis examines the connection between out-migration behaviors and measures of the quality of the previous agricultural season (i.e., the availability of food).

We evaluate the quality of the agricultural season using the following approach. We calculate an annual rainfall index, taking into account several different characteristics from each year. Each characteristic reflects important components of a successful rainy season in West Africa, acknowledged by academic studies as well as by local farmers (Mertz, Mbow, Reenberg, & Diouf, 2009; Nielsen & Reenberg, 2010).

The following measures are used to construct the index. First, **the total seasonal rainfall**. This measure is often used to capture the quality of a rainy season and is particularly important in small-holder agricultural settings. Growing season rainfall on its own can serve as a proxy for food production (Grace, Husak, Harrison, Pedreros, & Michaelsen, 2012, Marshall et al., 2011) and is frequently used as an indication of potential food need (see FEWS NET). Second, **the rainfall distribution during the season** is also important, as too much rainfall can cause problems with runoff or flooding and too little rainfall or too many days with no rainfall, can impact healthy plant growth (Mertz et al., 2009). A dry spell of two weeks, for example, is extremely difficult for plants, especially in the early stage of development and can cause major problems for the overall crop production (Sultan & Janicot, 2003; Laux et al., 2008). Third, the **onset of the rainy season (late start or on-time),** is an additionally critically important component of a strong growing season and has the potential to impact

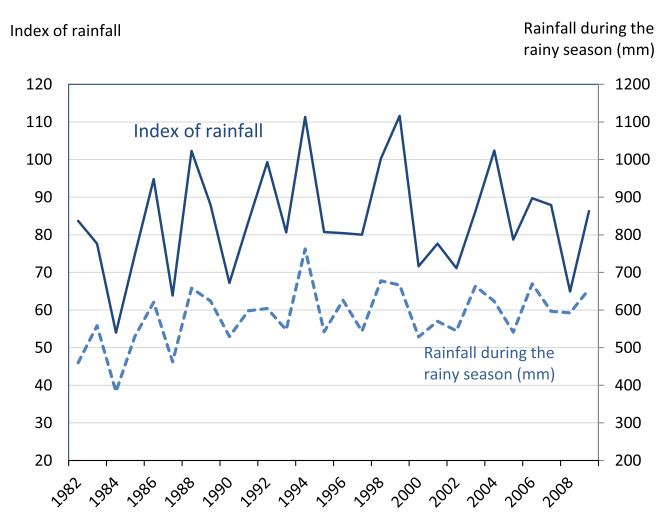

Fig. 1. Composite Rainfall Index and Rainfall using CHIRPS data.

the harvest (Ati et al., 2002; Steward, 1991). Finally, we consider the **quality of the past year** with the idea that individuals may make out-migration decisions based on how more than just the current season but with consideration to food storage and productivity of previous years (Reenberg et al., 2008). We construct a "rainfall index" based on the integration of these factors. Specific details of the rainfall index are available in the Appendix.

In Fig. 1 we plot the calculated rainfall index and the rainy season totals. The range of variation is about the same for both indicators (the ratio is 1 to 2 between the minimum and the maximum and we generally observe peaks and valleys during the same years, but the index shows more extreme variations as compared to the rainfall series.

Additionally, we construct a categorical rainfall variable, to evaluate three different scenarios in terms of the quality of the rainy season: *good, poor,* and *medium. Poor* include the three years that are distinguished by a particularly low rainfall indicator (below 70): 1984, 1987 and 1990. The class of *good* years corresponds to those with the highest rainfall indicator (more than 100): 1988, 1994, 1999 and 2004. The remaining 22 years of the 1981–2008 period are classified as *medium*.

6.2. Migration measures – macro and micro perspectives

We imagine that a poor rainfall year might have two effects on migration: a push effect for those who are in the village, or a delayed return effect for those who are still out of the village and may postpone their return (extend their absence) because of the poor season. Therefore, to measure the impact of rainfall on out-migration we consider a "population at risk" for out-migrating, or for not returning, to include people who are living in the village or who were living in the village recently.

We investigate community-level out-migration trends from a macro-level perspective where we look at community-trends by age and sex over time. We use this approach to "discover" and describe trends in out-migration in these rural villages as they relate to climate patterns and trends over time (Billari, 2015). We further investigate aspects of individual-level out-migration, to aid in the understanding of the micro-level components of rainfall's impact on individual behaviors (*ibid)*.

Out-migration was calculated at the scale of the village: an individual who is out of the village for at least three months (on January 1 of a given year, as well as at any point during the specified year) is classified as an out-migrant. Out-migration levels were calculated each year, among the individuals who have lived in the village at some point during the five preceding years.

While there is very limited variation in household characteristics related to education, wealth or assets, factors that are often correlated with out-migration decisions, we can evaluate a small suite of variables that may relate to how an individual responds to changes in rainfall. We use a selection of independent variables, including the calculated rainfall variable, and focus on the ways that variation in rainfall impacts the *duration* and *destination* of migration. Variables and accompanying descriptive information are presented in Table 1.

7. Results

The primary goal of this research was to investigate whether and how rainfall measures relate to out-migration. In this section we first describe the general trends in out-migration at an aggregate level. We then address the primary research question using aggregated, community-level results and then further explore individual responses to rainfall using regression analysis.

Table 1
Descriptive characteristics of variables used in the individual-level analysis using the out-migration as the unit of analysis.

Variables	Categories	Mean	Maximum	Minimum
Sex	Male = 1476; Female = 425			
Type of migration	Economic = 1578; Family = 105; Other = 216			
Migration rank		5.2	25	1
Age at migration (years)		19.7	29	15
Educational attainment	Primary = 323; Incomplete = 209; None = 1354; Not Recorded = 8			
Religion (at most recent survey)	Catholic = 678; Protestant = 289; Traditional = 921; Muslim = 13			
Season	Dry = 459; Rainy = 418; Harvest = 1024			
Dependent Variables				
Duration (years)		1.68	21	0.4
Categorical duration	1 year or less = 1400; More than 1 year = 501			
Destination	Rural areas = 452; Urban Areas = 1342; International = 104; Unknown = 3			

Note: The data is restricted to people aged 15–29 who emigrated for at least one three month period from the villages during the analysis period.

7.1. Migration patterns and trends

Temporary out-migration is common in many West-African countries and, as mentioned previously, it is routine in the villages under study in this analysis. Fewer than 10% of women and men reach their 20th birthday without at least one village departure of three months or more (Lesclingand & Hertrich, 2017). Out-migration should be understood not as an exceptional or unusual behavior but rather as a part of the way of life. Children grow up seeing people around them, including their own family members and fathers, coming and going. Out-migration is therefore very well integrated into each person's understanding of their own future paths. In fact, in contemporary rural Malian communities, like the ones here, it is dramatically less common for an individual to enter into adulthood without having experienced an out-migration.

We first evaluate out-migration behaviors with consideration to age and sex (Fig. 2a). For both sexes, out-migration is notably concentrated during adolescence and early adulthood. Out-migration follows a bell shaped curve, peaking at age 17 for women, and age 19 for men. At these ages, over 60% of young people are involved in out-migration. Note that rates are calculate among those who were recorded as resident in the village over the previous 5 years.

Youth out-migration has increased over the last three decades for both sexes (Fig. 2b and c). *For women* there was a dramatic increase in migrations since the 1990s (Lesclingand & Hertrich, 2017). This increase is directly related to the development of labor out-migration during adolescence: girls go to the cities to work as domestic servants with the aim of earning money to buy clothes and kitchen utensils (the "trousseau") before returning to the village to marry (Lesclingand, 2004; Hertrich & Lesclingand, 2012; Lesclingand & Hertrich, 2017). Marriage is considered as the end of youth for women and also as the end of autonomous migration. Consistent with this, data display a sharp decline in female out-migration after age 20 (Fig. 2c).

For men the practice of out-migration during adolescence was already established in the 1980s, the earliest period of time in our observation period. The use and diffusion of the plough during the 1970s and the resulting demand for draft oxen, underlies the firmly established patterns of male labor out-migration by this time (Lesclingand & Hertrich, 2017). Boys were routinely sent by their families to work as a cowherd for Fulani herders (a pastoralist/nomadic ethnic group present all over the region); boys were remunerated in head of cattle and this was an efficient means for families to acquire draft oxen at no monetary expense. This practice became the rule for young men, but women were never involved. Out-migration to Fulani areas became a first step in men's migratory pathways. Alternatively, the second stage of male out-migrations often involved moving to urban areas. Male labor out-migration is valued, by the family, as a contribution to family

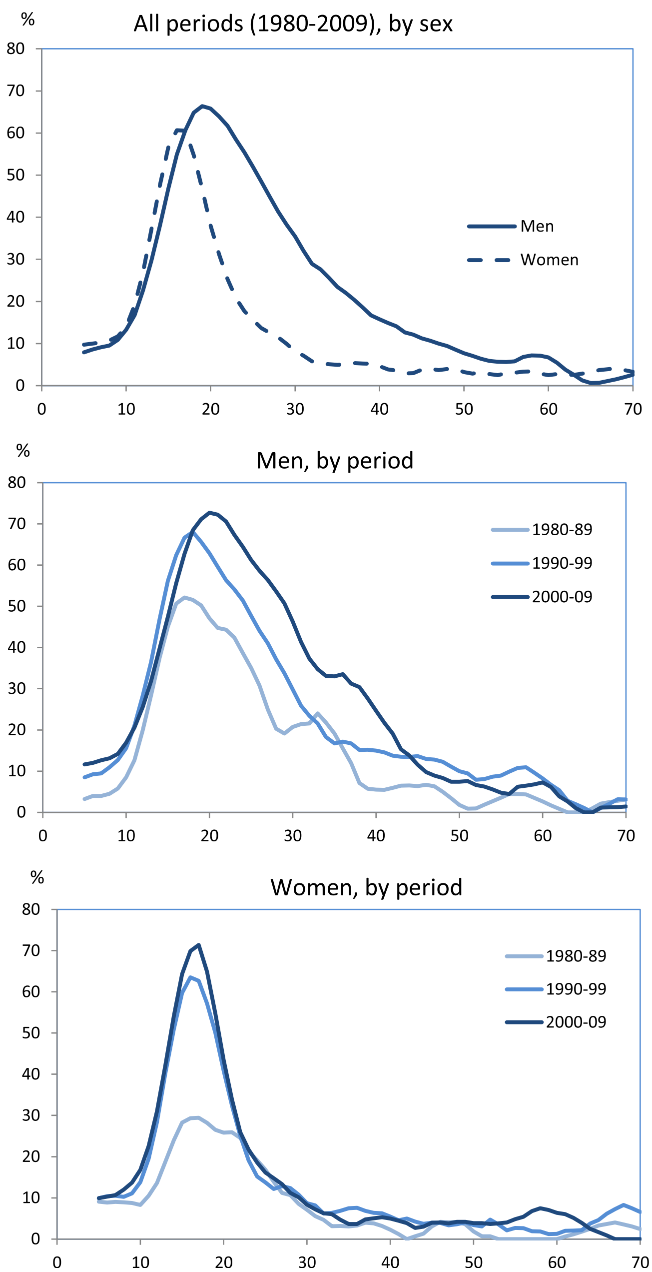

Fig. 2. Out-migration by sex and age. Pattern and trends (1980–2009). Proportion (%) of individuals living outside the village (at least for 3 months) at January 1st or at any other time of the year, among individuals who lived in the village (at least for 3 months) during the preceding 5 years (according the age reached during the year). (1 observation by individual/year followed during 1980–2009 period). Moving average on five points of age.

economics, while female labor out-migration is perceived negatively, as a self-motivated plan disconnected from family interests (Hertrich and Lesclingand, 2013).

Unlike women, there is no absolute expectation that men will end their labor out-migration once they enter marriage. While male out-migration decreases after age 20, in 2000–2009, it is still extremely common (over 40%) until age 30 and even until age 40 (over 20%) (Fig. 2b).

8. Is rainfall stress a driver of out-migration?

8.1. Aggregate indicators

Owing to the routine reliance on male labor out-migrations as part of the household economic strategy, one would expect that male out-migration is particularly sensitive to economic stress and would likely increase first to support the household. However other, more indirect, factors may be at play, including the potential of a weakening of the norms related to female and male mobility. If there is an acute food crisis, every possibility to externalize the feeding cost of family members (having fewer mouths to feed) might be considered positively. Thus, we may anticipate an increase in those types of out-migrations which, under normal circumstances, are socially discouraged. From this perspective, adverse climatic conditions could influence out-migration on a larger scale, including among those family members who have historically not borne the responsibility to ensure food supply for the domestic group.

In summary, if rainfall conditions are a key driver of out-migration, then we should observe differences in the levels of out-migration according the quality of the rainfall: more out-migrations after severe climatic conditions (poor harvest/food shortage) and fewer out-migrations when the rainy season was good (good harvest/food security).

We addressed this hypothesis at the aggregate level, through two basic tests: the first test (Fig. 3) compares the index of rain a given year to an index of out-migration the following year. Both indicators are relative indexes, where the value of the year is compared to the average of the 5-year period. In other words, we expect that a lower quality of the rainy season compared to the period average will produce a higher rate of out-migration compared to the period average of out-migration. The second test (Fig. 4) compares the level and pattern of out-migration for three categories of years: the three worse years of the 1981–2007 period according the rainfall index ("bad years"), the four best years ("good years"), and the other years of the 1981–2007 ("medium years").

Both approaches converge to disqualify our hypothesis. Indeed, there is no correlation between the indexes of out-migration and rainfall for males (aged 15–29) (Fig. 3). For women there is a correlation ($p < 0.1$) but not in the expected direction. In other words, a higher rainfall index, a better growing season, is correlated to higher rates of out-migration among women.

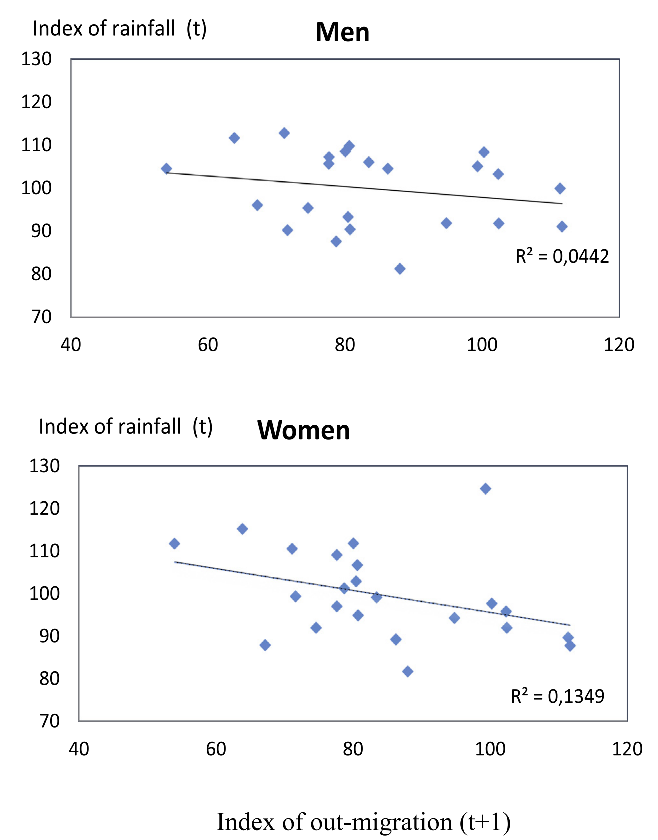

Fig. 3. Correlation between the index of rainfall (year t) and the index of out-migration (year t+1) at age 15–29. Years (1981–2008). The *index of rainfall* compares the rainfall of the year (t) to the moving 5-years average (t−2, t+2) and includes additional components (regularity of rainfall distribution, onset of rainy season, quality of the rainfall the preceding year). The *index of out-migration* compares the out-migration indicator at age 15–29 for the year (t+1), to the to the moving 5-years average (t−1, t+3).

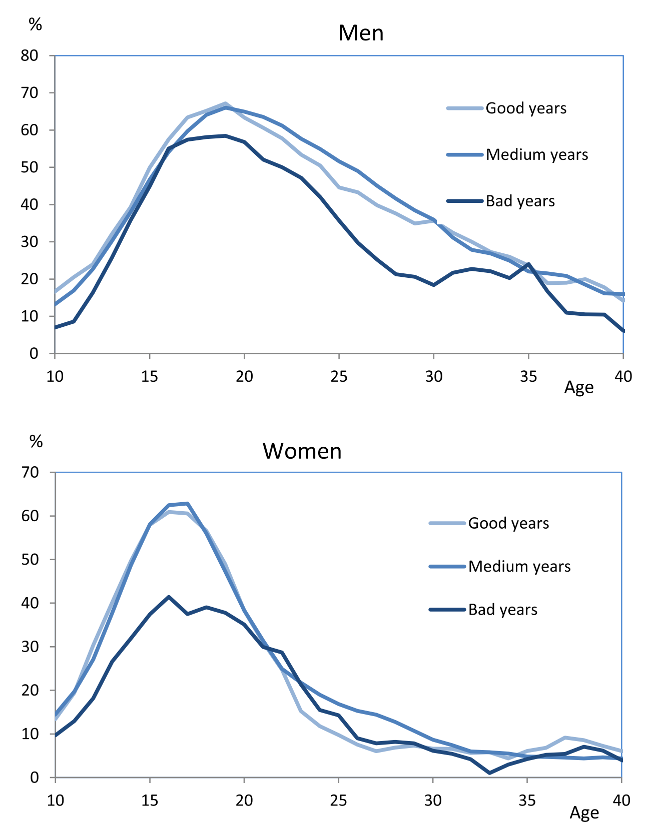

Fig. 4. Out-migration according the index of rainfall. By sex and age. (1980–2009). Proportion (%) of individuals living outside the village (at least for three months) at January 1st or at any other time of the year, among individuals who lived in the village (at least for three months) during the preceding five years (according the age reached during the year). (1 observation by individual/year followed during 1980–2009 period). Moving average on five points of age. "Bad years": years following an especially low level of rainfall (Index < 70). 1985, 1987, 1991. "Good years": years following an especially good level of rainfall (Index > 100). 1989, 1994, 2000, 2005. "Medium years": others years from the 1980–2009 period (70 ≤ Index ≤ 100).

Table 2
a-b Regression results – destination and duration of migration characteristics evaluated by sex and according to length of migration among individuals aged 15–29. All migrations that are at least 3 months long and that occurred between 1982 and 2008 are included in the analysis.

	Destination – Men 0 = rural; 1 = urban	Coeff.	Std. Error		Coeff.	Std. Error	
Type of migration							
	Economic	baseline			baseline		
	Family and other	−1.26	0.26	***	−1.36	0.26	***
Rank		0.59	0.16	***	0.6	0.16	***
Rainfall Index (categorical)							
	Bad	baseline			baseline		
	Normal	0.24	0.21		−0.02	0.22	
	Good	0.51	0.25	*	0.27	0.26	
Age		0.28	0.04	***	0.27	0.04	***
Decade							
	1980s				baseline		
	1990s				0.74	0.21	***
	2000s				0.71	0.2	***
N	1473				1473		
AIC	1378				1364		

	Destination – Women 0 = rural; 1 = urban	Coeff.	Std. Error		Coeff.	Std. Error	
Type of migration							
	Economic	baseline			baseline		baseline
	Family and other	−0.93	0.3	**	−0.92	0.32	−0.93
Rank		−0.2	0.25		−0.23	0.26	−0.2
Rainfall Index (categorical)							
	Bad	baseline					baseline
	Normal	−0.07	0.49		−0.16	0.48	−0.07
	Good	0.16	0.58		0.2	0.59	0.16
Age		0.07	0.05		0.08	0.05	0.07
Decade							
	1980s				baseline		
	1990s				0.64	0.38	
	2000s				0.6	0.39	
N	424				424		
AIC	422				420		

+indicates a p-value < 0.1; *indicates a p-value < 0.05; **indicates a p-value < 0.01; ***indicates a p-value < 0.001

	Duration – Men 0 = no more than 1 year; 1 = more than 1 year	Coeff.	Std. Error		Coeff.	Std. Error	
Type of migration							
	Economic	baseline			baseline		
	Family and other	0.55	0.21	**	0.51	0.21	
Rank		−0.19	0.14		0.22	0.14	
Rainfall Index (categorical)							
	Bad	baseline					
	Normal	0.42	0.26		−0.02	0.28	
	Good	0.64	0.30	*	0.14	0.32	
Age		0.02	0.02		0.02	0.02	
Decade							
	1980s				baseline		
	1990s				1.21	0.24	***
	2000s				0.81	0.24	***
N	1473				1473		
AIC	1561				1531		

	Duration – Women 0 = no more than 1 year; 1 = more than 1 year	Coeff.	Std. Error		Coeff.	Std. Error	
Type of migration							
	Economic	baseline			baseline		
	Family and other	−0.75	0.80	**	−0.70	0.28	*
Rank		−0.45	0.22	*	−0.47	0.22	*
Rainfall Index (categorical)							
	Bad	baseline			baseline		
	Normal	−0.07	0.42		−0.27	0.45	
	Good	0.38	0.49		0.04	0.52	
Age		−0.07	0.04	*	−0.10	0.04	*
Decade							
	1980s				baseline		
	1990s				0.46	0.35	
	2000s				−0.05	0.34	
N	424				424		
AIC	555				534		

+indicates a p-value < 0.1; *indicates a p-value < 0.05; **indicates a p-value < 0.01; ***indicates a p-value < 0.001

When comparing out-migration rates between the bad, good and the medium years, we observe the same relationship – rainfall and out-migration are related, but not in the expected direction. For women, as well as for men, out-migration is less common when the rainy season was bad, while good and medium years display the same pattern as each other and indicate increased out-migration. The gap exists for ages where out-migration is the most common (between 13 and 20 for women, between 18 and 35 for men), and is more notable for women than for men.

8.2. Individual-level analysis

Given the results suggested by the aggregate analysis, bad rainfall years reduce out-migration, we investigate how these seasonal experiences interact with individual characteristics and out-migration behaviors among people aged 15–29. To develop an understanding of each individual out-migration we build on the findings of related research (Henry et al., 2004; Findley, 1994) and evaluate the variability in temporary out-migration behaviors by focusing on duration of out-migration and out-migration destination as they relate to seasonal rainfall variability. This analysis is conducted evaluating each trip among those who have left the village and returned to the village during the period under investigation.

We include age at the time of the out-migration, type of out-migration – economic or other, rank of the particular out-migration for the individual (the number of times a person has migrated at that point), and rainfall index as independent variables. Because of country-level shifts in development as well as an increase in rainfall amounts (there are more "bad" years in the 1980s for example, than in the 2000s) we include dummy variables for the decade of the out-migration. Additionally, we consider the categorical rainfall index alone and with the decade dummy variable because of the correlation between decade and the categorical rainfall index. Given the sex-based differences in data collection we also evaluate out-migrations done by men and women separately.

We model the destination of each departure from the village, and we treat this variable as a categorical variable – rural versus urban destinations. The duration of the out-migration is also used as an outcome variable and is also modeled as a categorical dependent variable[4] comparing out-migrations that are 1 year or less to those that are greater than 1 year. We focus on these shorter duration categories because comparing continuous periods of time would be inappropriate given the way the data was collected (trips that began more recently would naturally be constrained in duration).

Starting with destination of the out-migration – rural or urban, Table 2a, the results for the male out-migrants indicate the significance of rainfall, the reason (or type) of out-migration and the age and rank of the out-migrant. The first model shows that during years characterized as "good" rainfall years, men are more likely to out-migrate urban areas. When we include decade in the model, rainfall is no longer significant – indicating a correlation between decade and rainfall index. The results indicate that men were more likely to go to urban areas in the 1990s and 2000s as compared to the 1980s. Because a variety of factors related to out-migration – including country-wide, political and economic factors – changed over the time period, it is possible that rainfall may not be the driving force in out-migration behavior. For women, we see only the reasons for out-migration – when women out-migrated for non-economic reasons they were more likely to go to rural areas, regardless of the quality of the season. The results also show that there has been no significant change in terms of the likelihood of rural versus urban destination when comparing women's behavior over the 30-year period.

Next, when evaluating, duration of out-migration (Table 2b) rainfall is only a significant predictor (with a p-value of <0.05) of duration of out-migration for men and when not considering the changes over time. The results suggest that during "good" rainfall years as compared to "bad" rainfall years, the duration of an out-migration is longer. In the 1990s and 2000s, the duration of men's out-migration is more likely to be longer as compared to the duration during the 1980s, regardless of rainfall. For both the men and women out-migrants in the sample, out-migration for "family and other" purposes (as opposed to economic purposes) is correlated to the duration of out-migration – among men, longer duration trips are associated with "family and other" purposes, while among women "family and other" purposes are associated with shorter out-migrations. These results are consistent for women even when considering changes over time, but are only significant for men when not considering changes over time.

9. Conclusion

In this project we combine unique highly detailed out-migration histories gathered over 25 years in two rural Malian communities. Because these two communities are rural subsistence communities with heavy dependence on rainfed agriculture, they are extremely vulnerable to anticipated warming and drying climatic changes of the region. By identifying the linkages between climate change, vulnerability and out-migration in these communities we can use this research to further scientific understanding of demographic response to climate change.

Our results suggest that a poor rainy season, the 1984 season for example, does not correlate to extreme or even higher than average rates of out-migration for either men or women. Even after accounting for some known sources of variability, age, sex and out-migration history, a decrease in rainfall does not directly lead to a higher out-migration index. Rather, the results suggest that during bad years, especially during the 1980s, the out-migration index is lower. We propose several explanations for these lower levels of out-migration. First, given that a failed/poor rainy season can often be experienced by other communities within the region, it could be that people had no where else to go where they could reliably count on finding work. Second, the resources needed to out-migrate could be unavailable during a resource strained time (see Findley, 1994; Hampshire, 2002). Instead of families investing in the costs associated with out-migration they could decide to reserve their resources in anticipation of later need. Similarly, the resources needed to fund a marriage party or to support a new wife in a household may be limited reducing women's out-migration for marriage purposes. Additionally, food aid, including food for work programs, could have provided alternative means for securing food during hard times.

And, for the third potential explanation, we actually suggest a potential reformulation of the "climate as push-factor" model, particularly in communities where circular migration is routine. The standard approach, where climate stress is considered as a push factor, implicitly considers that the reference behavior is "not to move". However, in contexts where circular migration is commonplace and non-migration is rare, the framework may need to be revisited (see the discussion of *sedentary bias* in Castles, 2010). In other contexts, we see that a response to economic stress is to

[4] We estimate regression coefficients using logistic regression models for the destination outcome variable. For duration of out-migration we use standard linear regression. These models are evaluated separately for each sex. Independent variables used in the analysis are presented in Table 1. Cluster adjusted standard errors are estimated as, in some cases, there are repeated observations (trips) for a given individual.

modify the "normal" behavior – we observe shifts in fertility behavior, marriage behavior, educational attainment, even childrearing behavior, all tied to different experiences with economic crises or changes. What if, as a response to climate driven economic stress in places where out-migration is routine, people change their out-migration behaviors? Would this economic stress therefore result in a change in out-migration behaviors among people who routinely migrate resulting in more people remaining in their communities? In other words, in the context of an economic crisis, as driven by a poor rainy season, could we perhaps observe a reduction in the tendency to out-migrate?

Other researchers, Hampshire (2002) and Findley (1994), for example, have explored similar ideas in their research of Sahelian migration characteristics and highlight the dynamic nature of behaviors related to mobility. Our results do indicate a change over time in behaviors at the micro- and macro-levels. An overall increase in out-migration and some changes in duration and destination of trips. These results could occur because the rainy seasons have been somewhat improving over time or because the villagers modified their behavior over a longer time scale after experiencing the major drought of 1984 or because international and domestic changes created changes in pull-factors. In Hampshire's (2002) study of Fulani in Burkina Faso she reminds readers that out-migration in some communities may be more about maximizing livelihood security rather than coping with livelihood failure. Our results support Hampshire's approach in these Sahelian communities as well.

While our communities cannot, and do not, represent all communities in the developing world, or even in Mali, they provide an important case study to evaluate established theories of responses to weather and climate in highly vulnerable subsistence communities. Further investigation of how the individual or household unit responds to climate changes will be useful in further understanding the climate-migration connection. Future research includes an analysis of recurrent events to evaluate how experiences with an extreme shock (like the 1984 drought) shape future out-migration behaviors, or to evaluate how repeated experiences with drought can serve to motivate a permanent out-migration. Additional research on different spatial scales of coping strategies and how those interact with individual decisions to out-migrate, modify fertility or change marriage/divorce plans will also be required to understand the diversity of responses to climate induced resource stress.

10. Conflict of interest

The authors have no financial/personal interest or belief that could affect their objectivity for this submission.

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Appendix

The rainfall index was developed using insight from remote monitoring programs (Climate Hazards Group and Famine Early Warning System Network) and further supported by field work in the countries as well as the cited qualitative investigations of farmer's perceptions of and experience with climate change. The index was also driven by the observed data as means, medians, and modes were used to identify cut-points in time and amount of rainfall, depending on the particular component of the index. The aim was to produce a measure that captured the multiple factors that might influence perceptions of and outcomes related to agricultural production in this particular context and that reflected the actual rainfall experiences. Details of the Index's construction follow.

Rainfall index

1) Annual rainfall
   a) R(t) = Total rainfall during the rainy season, t = 1981–2009
   b) Index $IR(t) = R(t)/(\Sigma\ R(t-2) - R(t+2)/5) * 100$
2) Seasonal Rainfall Variability – focus on very low performing time periods during the rainy season
   a) Dminus(t) = number of 10-day intervals with very low rainfall (very low rainfall is defined when the observed value is less than or equal to 85% * mean of the 10-day interval over the time period 1981–2009)
   b) Dminus_bis(t) = number of 10-day intervals where two periods of very low rainfall are back to back
   c) Index Dminus(t) =
      i) if Dminus(t) > 2 then IDminus(t) = 0.9
      ii) if Dminus(t) > 2 & if Dminus_bis(t) > 0 then IDminus(t) = 0.8
      iii) otherwise = 1
3) Start of Season: on-time or late
   a) On time = Rainy season starts in mid/late May
   b) Late if starts in June or later
   c) IndexLate(t) =
      i) If late = 0.9
      ii) otherwise = 1

Partial Rainfall Index: $I(t) = IR(t) * \text{Index Dminus}(t) * \text{IndexLate}(t)$

4) Past year's rainfall
   a. If the preceding year's index, I(t) < 0.88 then IPast(t) = 0.9

Rainfall Index $(t) = I(t) * IPast(t)$

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